THE LIFE HISTORY AND ECOLOGY OF *POTENTILLA ROBBINSIANA*

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Plants with restricted distributions have received increasing attention recently because of their obvious vulnerability. *Potentilla robbinsiana* Oakes (*ex* Torrey & Gray, 1840) is an extreme case in that it survives, in significant numbers, on a single site in the alpine zone of Mt. Washington. This refugium consists of a single hectare of barren landscape bisected by one of the most heavily travelled paths in North America, the Appalachian Trail.

Potentilla robbinsiana was discovered by James Robbins in 1829 (Pease, 1917) and described by the botanist-explorer William Oakes (Torrey & Gray, 1840).

But even before its discovery, *Potentilla robbinsiana* had felt the hand of man. Abel Crawford built his famous path (now part of the Appalachian Trail) through the center of the *P. robbinsiana* colony in the summer of 1819 (Burt, 1960). In 1840, the trail was converted to a bridle path opening the way to horseback parties. We have no knowledge of changes in the trailside *P. robbinsiana* population during the 1800's. It is likely that most travellers of that day were unaware that they were trampling the small *P. robbinsiana*.

The quest for new information on the distribution of plants, coupled with the collecting of herbarium specimens, also took a toll in the 1800's. Some 40 herbarium sheets, containing more than 100 plants, have been counted in the various herbaria in New England.

Edward Tuckerman made collections of *Potentilla robbinsiana* at two locations, both now extinct. One was made in 1839 on a "stony tract on the northeast side of the peak of Mt. Washington." This is in the vicinity of the location on which the Mt. Washington Toll Road was constructed in the summer of 1861 (Burt, 1960). Tuckerman's other collection was made at Mt. Mansfield, Vermont. No other known collection of the plant was ever again made at either of these sites.

Much later, *Potentilla robbinsiana* was found in the Franconia Range at two locations, a north station in 1897 by F. Endicott and a south station in 1915 by M. L. Fernald (Steele, 1964). The north station has not been relocated in nearly 65 years and is undoubtedly extinct. The south station was relocated by Steele in 1963; it con-

sisted of only 3 small clumps of plants. This station has not been found since 1965 and Steele (personal communication), after searching the area in 1979, believes the plants are dead.

In 1970, Donald White discovered a colony consisting "of only a few plants" at an undisclosed location in Vermont (Countryman, 1978). These few plants in Vermont are now believed to be the only natural population of the plant apart from the Appalachian Trail colony on Mt. Washington.

Little was known of the population stability at the Appalachian Trail *Potentilla robbinsiana* colony on Mt. Washington until very recently. Steele (personal communication) has estimated that the plants are confined to about ¼ of the territory they occupied in 1934. Harris (personal communication) observed *P. robbinsiana* growing on both sides of the trail as recently as 1965. By 1972, the plant was gone from that part of the barren to the west of the trail. On the east side, the nearest plant is now 8.6 meters from the edge of the trail.

The purpose of my research was to study the life history and ecology of *Potentilla robbinsiana* and to document the population changes of the colony on Mt. Washington. I hoped to discover the causes of its decline and to suggest protective measures which would ensure its survival.

The *Potentilla robbinsiana* colony on Mt. Washington grows on a fell-field with a stony pavement, subject to frost heaving in every month of the year. The stony surface layer protects the loamy sand soil from the high winds and severe storms that would otherwise blow or wash it away. The soil is derived from fine-grained mica schist bedrock and is weakly calcareous (Löve & Löve, 1965; Fowler, 1971).

Potentilla robbinsiana is a very low, almost stemless plant with a dense tuft of leaves above the ground and a deep taproot beneath it. The dense rosette of compound leaves consists of toothed leaflets in threes. In the early spring, there is no sign of life, only the rosette of last year's dead leaves. The new leaves begin development in May. Occasionally, after unusually warm weather, a few flowers will bloom during the last week of May. In most years, flowering begins during the first week of June, peaks between the 10th and 20th, and is complete by the 26th of June (Figure 1). An occasional blossom

Figure 1. *Potentilla robbinsiana* flowers in mid June. The leaf rosette diameter of this plant is 2.4 cm and its age is estimated at 15 to 25 years.

can be found almost anytime until October. No plants with a leaf rosette diameter of less than 1.4 cm was ever observed to flower.

An important objective was to determine the area occupied by the *Potentilla robbinsiana* colony. I mapped the exact location of each plant growing on the perimeter of the colony (Figure 2). While the fell-field habitat was approximately 1 hectare in size, the *P. robbinsiana* occupied only 1142 m^2 or about 1/10th of it.

The entire 1142 m^2 was searched carefully and all *Potentilla robbinsiana* of flowering size (rosette diameter of 1.4 cm or larger) were counted. I found 1801 plants. Fifty-eight 1-m^2 quadrats were randomly distributed over the area to measure the size distribution of the population. The population consisted of 3721 established plants, 52% of which were less than 1.4 cm in diameter or non-flowering (Figure 3).

An additional component of this population was the newly germinated plants less than one year old. I found 772 newly germinated seedlings during a single growing season, yet only 328 remained at the end of the first summer. The total plant population at the end of the growing season was then 4,049.

About 50 to 75% of the mature plants flowered each year producing an average of three (3.1) flowers each. However, a single large plant was observed to produce as many as 30 flowers. Löve and Löve (1965) believe that *Potentilla robbinsiana* produces seed through apomixis. The smooth green achenes, clustered in the dried flower heads, are apparent by the end of June. The maturation of the seeds, in mid to late July, was signaled when the seed coat turned brown (Figure 4). The average fruiting plant produced 21 viable seeds (range 1–115). The total seed production of the entire colony averaged approximately 24,000 viable seeds. Seed viability was high, averaging 90.4%. The mean weight of an oven—dried viable seed was 20 μg. The seeds were dispersed by simply falling to the ground on dry, windy days. Seldom did a seed travel more than a few centimeters. In no case were new seedlings ever discovered more than 14 cm from the mother plant. For this reason, the plants tend to be clustered and very slow to become reestablished if eliminated from some part of their natural habitat. The seeds germinate, after overwintering, in June and July. It appears to me that a major portion of the seeds produced annually germinate, but do so under less than favorable conditions, and quickly die. Approximately 800

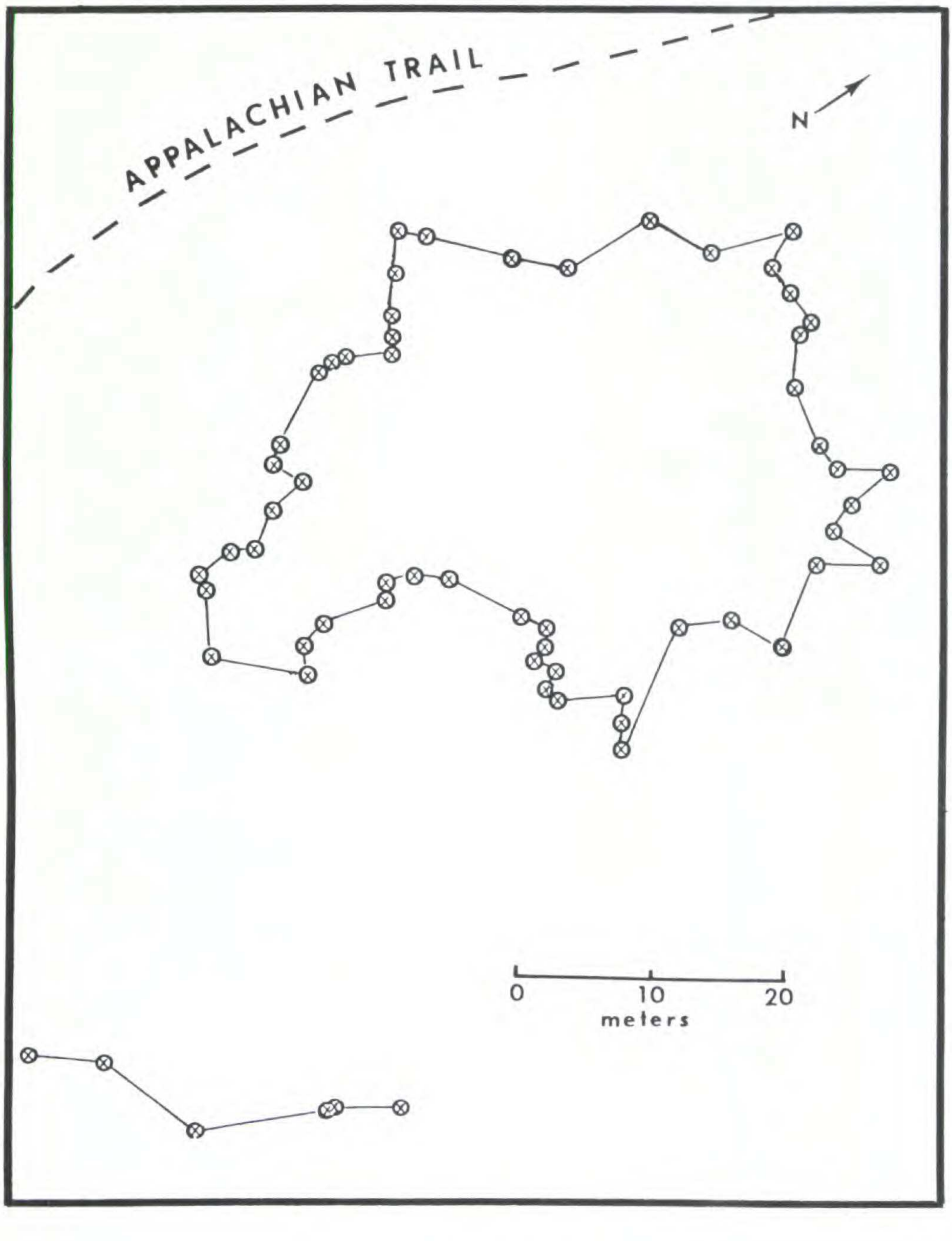

Figure 2. Peripheral plant locations of the *Potentilla robbinsiana* colony are mapped. The area enclosed is 1142 m^2.

new seedlings become established each summer, but only about 40% survive until October.

The harsh climate is the most important natural cause of plant mortality. Most seedling mortality occurred during hot, dry periods and is believed due to drought. During the spring and fall, frost heaving is the most common cause of plant death. No animals or insects were ever found to cause damage to seeds or seedlings. No diseases were noted. While *Potentilla robbinsiana* suffered high rates of mortality during the first years after germination, mortality declined among surviving plants and persistence for one or more decades is common. Some of the largest plants are estimated to be 40 years old.

Human activities are the major threat to the survival of *Potentilla robbinsiana*. Hiker traffic on the Appalachian Trail has increased dramatically in recent years. The nearly barren *P. robbinsiana* habitat is open and offers no natural obstacle to the hiker who wishes to step off the trail to rest, or to the group of hikers who prefer to walk abreast. A plant may be crushed in the process, but even more damaging is the shifting and dislodging of the stony pavement that occurs as hikers walk along. The abrasion and churning caused by the hiker's footsteps can eliminate the protected spaces between the individual stones, which often hold fine soil and organic particles. These minute sheltered spots are the nurseries for the newly germinated *P. robbinsiana*, and it is only here that they can become established. When the stony pavement is disturbed by hikers, the soil between the stones loosens and is soon blown or washed away. Once this precious bit of soil is lost, there is little or no chance of establishing and nurturing a seedling until the soil is replaced by natural processes. The hiker travel zone is widening and further destruction of the *P. robbinsiana* will likely occur. The only long-term solution to the problem is to greatly reduce the human traffic. A logical way to achieve this would be to relocate approximately ½-mile of the Appalachian Trail.

Regardless, we must provide this rare plant better protection than it has received in the past. The reduction of man's impact on this fragile alpine plant community is the first step in providing for its survival in an unimpaired form.

The need to establish new colonies of *Potentilla robbinsiana* to ensure its survival was recognized by Harris (1967). He moved

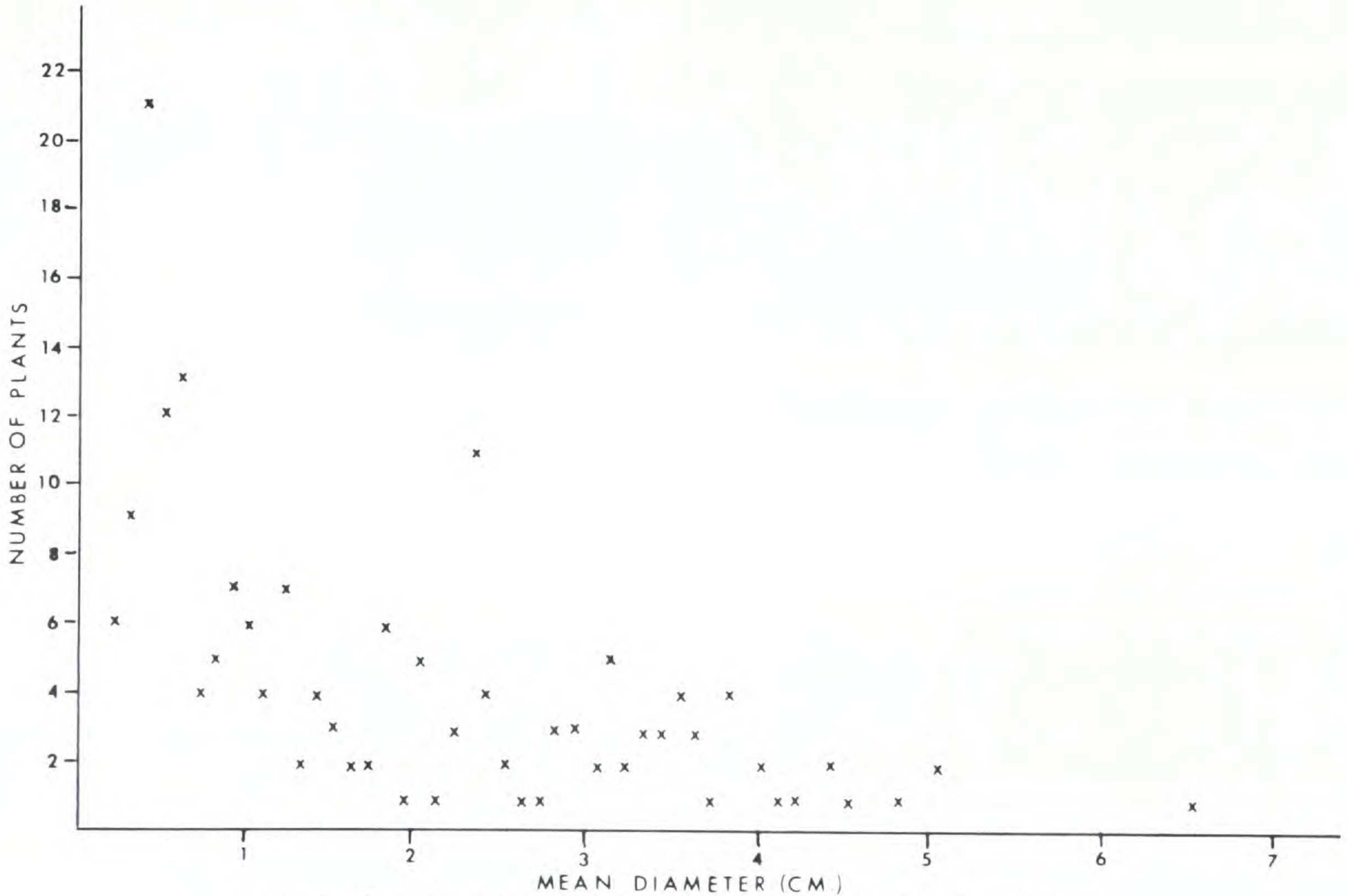

Figure 3. *Potentilla robbinsiana* rosette diameter distribution. The mean plant diameter is 1.2 cm. The plants do not flower until they are 1.4 cm or larger.

Figure 4. The mature seeds of this *Potentilla robbinsiana* are in the process of being shed. They fall to the ground near the mother plant.

plants from the Mt. Washington colony to a similar habitat about 900 m away. His transplants died for unknown reasons (A. R. Hodgdon, personal communication). I began transplantings in 1974. Seeds had been collected in July of the preceding year. Germinated seeds were planted in the greenhouse in February. The seedlings were grown in styrofoam blocks with planting cavities of two sizes: 40 and 125 cc. The blocks were filled with an artificial soil of equal parts peat, vermiculite and perlite. They were fertilized weekly with a complete nutrient solution. By mid-June, the plants were 3 to 5 cm in diameter, as large as the natural plants on Mt. Washington after a decade or more of growth. Transplanting to plots on Mt. Washington was done in late June and July. The seedlings were planted by forcing a dibble into the ground; then removing a seedling from the container complete with soil and placing the root-bound soil cone into the dibble hole. Eighteen plantings were made to provide a range of environmental conditions of varying aspect, elevation, and plant competition.

Mortality during the first summer was very low as most losses of mature plants tend to occur during the dormant season. After three years, heavy mortality had occurred on some of the planting sites. At lower elevations, where the fog was less frequent and the planting site was warm and dry, survival was nil. On the cool, foggy northwestern slopes of the upper mountain, the survival rate was very poor. Where plant competition by sedges and dwarf shrubs was significant, plant mortality rates were also high. *Potentilla robbinsiana* did best on the barren stony sites, where conditions were most similar to those of the natural colony. On these sites, transplant survival ranged from 17 to 90 percent, averaging 65 percent. Many of these transplants are now producing flowers, seeds, and seedlings.

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